1960

Electrophysiological relationships between contra-lateral and ipsi-lateral stimulation, recorded from the auditory cortex of the cat

Donald David Thompson
Lehigh University

Photoduplication Service
Lehigh University
Bethlehem, Pa.

Job No. _____

REQUISITION FOR PHOTODUPLICATION SERVICES

Item No.	Type of Reproduction	Complete Description	Unit Price	Item Price
1 only	Microfilm (negative)	Thompson, Donald D. Electrophysiological relationships between contra-lateral and ipsi-lateral stimulation, recorded from the auditory cortex of the cat. M.S.Thesis L.U.1960		

Microfilm reel and box _____
Microfilm minimum charge _____
Postage, as required _____

TOTAL CHARGE _____

This work is done under the conditions stated on the back of this sheet, to which I agree.

Authorized Signature Robert S. Taylor Department Library

Account Number 290-5 Date October 6, 1960

Personal payment _____ (PREPAYMENT WILL NOT BE ACCEPTED. Applicant will be billed by the University on completion of work.)

If non-Lehigh request, name and address of institution:

_____

_____

Is copyright agreement on file? _____

ELECTROPHYSIOLOGICAL RELATIONSHIPS BETWEEN CONTRA-LATERAL AND IPSI-LATERAL STIMULATION, RECORDED FROM THE AUDITORY CORTEX OF THE CAT

by

Donald David Thompson

A THESIS

Presented to the Graduate Faculty

of Lehigh University

in Candidacy for the Degree of

Master of Science

Lehigh University

1960

This thesis is accepted and approved in partial fulfillment of the requirements for the degree of Master of Science in Psychology.

21 September 1960

Nathan B Gross
Professor in Charge

21 September 1960

Head of the Department

Josef Brozek

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Dr. Nathan B. Gross for his invaluable instruction in technique and for his direction in the formulation and completion of this thesis.

The author also wishes to give acknowledgement to Dr. Soloman Wienstock and Dr. Arthur Brody for statistical consultation.

TABLE OF CONTENTS

Electrophysiological Relationships Between Contra-lateral and Ipsi-lateral Stimulation, Recorded From the Auditory Cortex of the Cat

INTRODUCTION

Retrograde degeneration studies of the auditory system have established that there is bilateral representation of each cochlea on the cerebral cortex (1, 2, 3, 8). The number of fibers from the contra-lateral cochlea appear to be more abundant than those from the ipsi-lateral cochlea (1, 3, 5, 6). Electrophysiological data have been collected relative to this problem using click stimulation which does not consistantly support the anatomical findings (3, 6).

The present study was designed to re-examine the question of whether the contra-lateral connections are more abundant than the ipsi-lateral connections on the same cortex. For this purpose electrophysiological recordings from the same cortex, using pure tones, are to be studied. In addition, it is the purpose of the present study to determine whether the various sub-acoustic response areas may be differentiated in terms of ipsi-lateral versus contra-lateral stimulation.

METHOD

Animal Preparation

Cats were anesthetized with Dial. The femoral vein was catheterized so that saline or additional amounts of Dial could be injected intravenously. The trachea was exposed and cannulated. Both pinnae were partially excised and specula were secured in the remaining portions. The cerebral cortex was then exposed unilaterally. A camera lucida drawing was made of the "auditory area" and included the sulci and most of the blood vessels. A green filter was used to increase the contrast between the blood vessels and cerebral cortex in making the drawing.

Stimulating Equipment

A block diagram of the stimulating and recording apparatus is contained in Figure 1. The tones were generated by a General Radio Type 1304B oscillator. A Grason-Stadler Electronic Switch Type 829-S56 and a Grason-Stadler Type E-3299A Interval Timer were used to control the tones. The rise-fall times were approximately 6 msecs. and the duration of the tone was approximately 0.5 sec. A Hewlett-Packard 350-A Attentuator Set was used to control the sound intensity. An impedence matching transformer was placed between the attenuator set and a Permuflux PDR-10 earphone

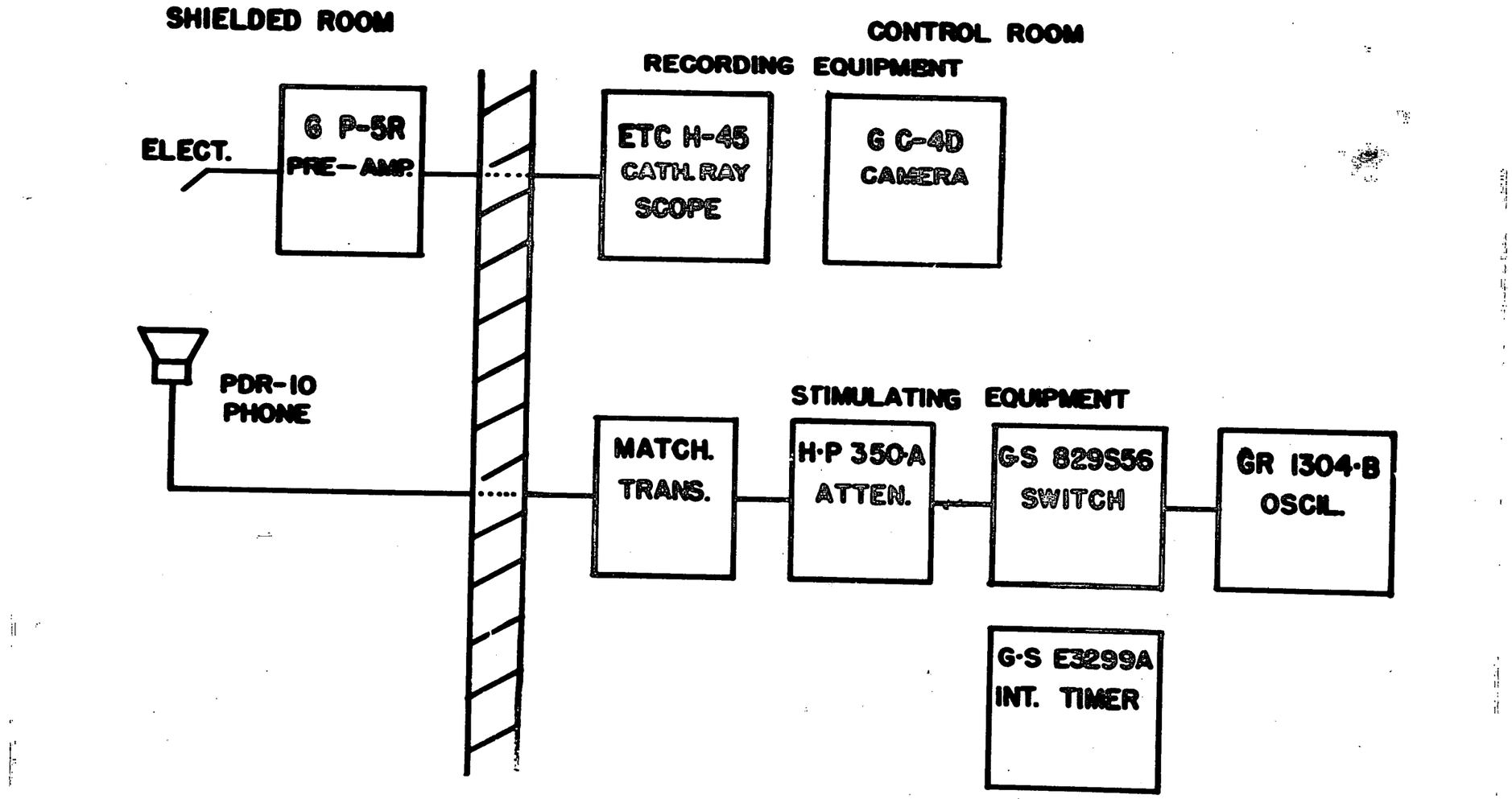

Figure 1. A block diagram of the stimulating and recording apparatus

which was used as the transducer. The earphone was enclosed in a heavy aluminum casting and connected to one of the specula by a polyethelyne tube. The tube was 8.5 mm in diameter and 150 mm long and contained a piece of yarn.

Recording Equipment

The bio-electric potentials were recorded with a platinum electrode, 0.014" in diameter, and were amplified by a Grass P-5R balanced preamplifier. A manipulator was used for accurate placement of the electrode. The potentials were displayed on an Electronic Tube Corporation Type H-45 oscilloscope. The traces were recorded on film with a Grass Kymograph Camera, Model C-4D.

Procedures

Exploration: Either 500 or 10,000 cps. was used as the stimulus. The intensity of the tone was arbitrarily set at about 30 db. below the 0.5 volt output of the oscillator. Recordings were made from the cortex contra-lateral to the ear that was stimulated. Oil soaked cotton was placed in the non-stimulated ear.

Figure 2 shows a lateral view of the cerebral cortex of the cat with some of the response areas outlined. Figure 3 shows the area bounded by the suprasylvian sulcus and extends ventrally to include parts of the insular and temporal polar gyri. Areas AI and AII have been arbitrarily subdivided into 6 sub-areas.

In the exploratory phase the electrode was systematically moved through areas AI, AII, Ep, Tp and In. At each electrode placement, the response amplitude was estimated and was recorded on the camera lucida drawing of the brain. The electrode placements were made under 2.5x optical magnification and under a green filter. Whenever possible electrode placements were made at arterial junctions for ease of replacement of the electrode.

Measurements: From the data obtained during the exploration phase, six points were chosen for further study. The largest and most stable of the responses in each of the subdivions were chosen whenever possible.

The following data were obtained from each point: 1) The threshold. The threshold is defined here as the minimum sound intensity required to cause

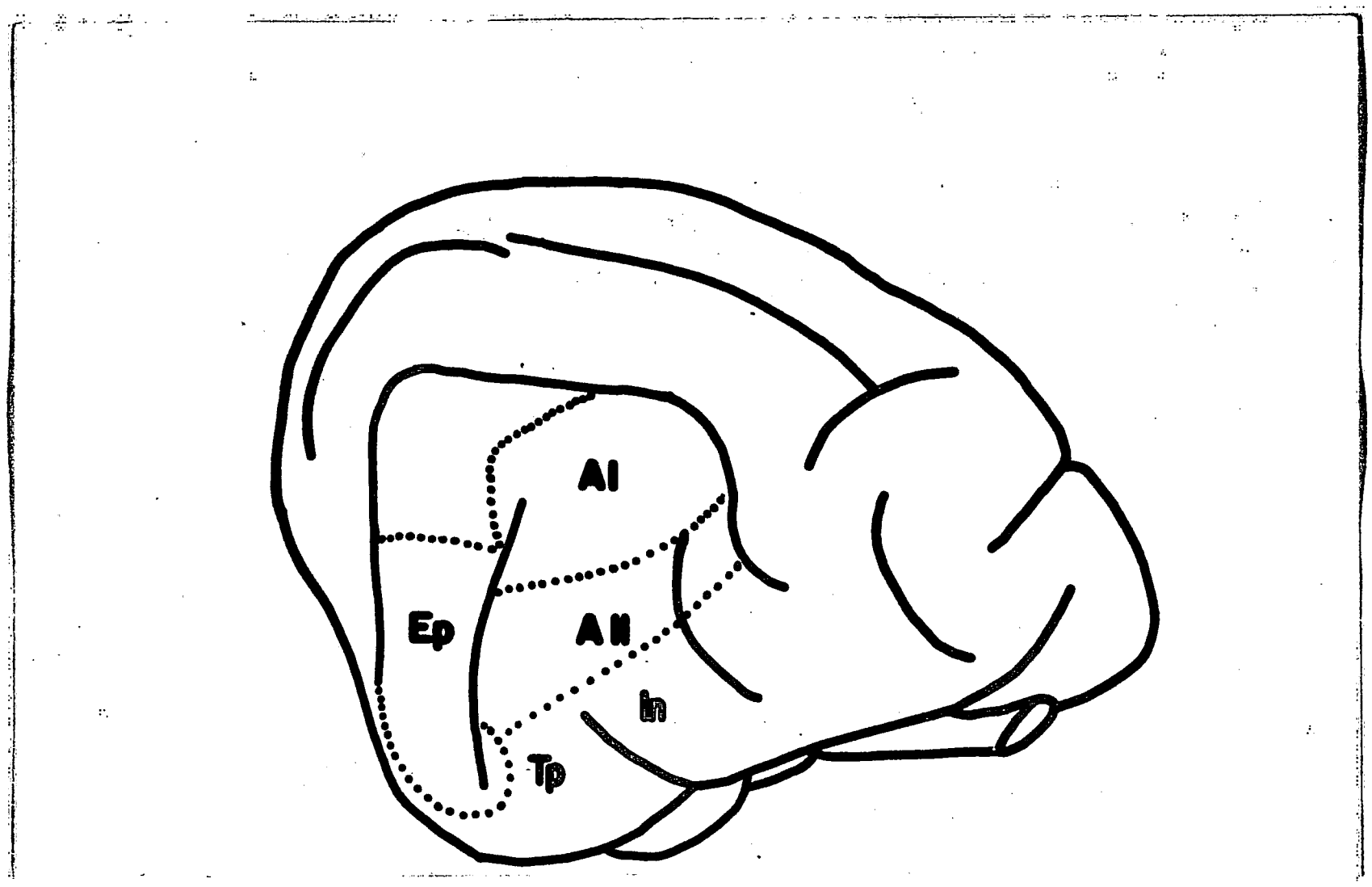

Figure 2. Lateral view of the cerebral cortex of the cat with response areas studied, labeled and outlined.

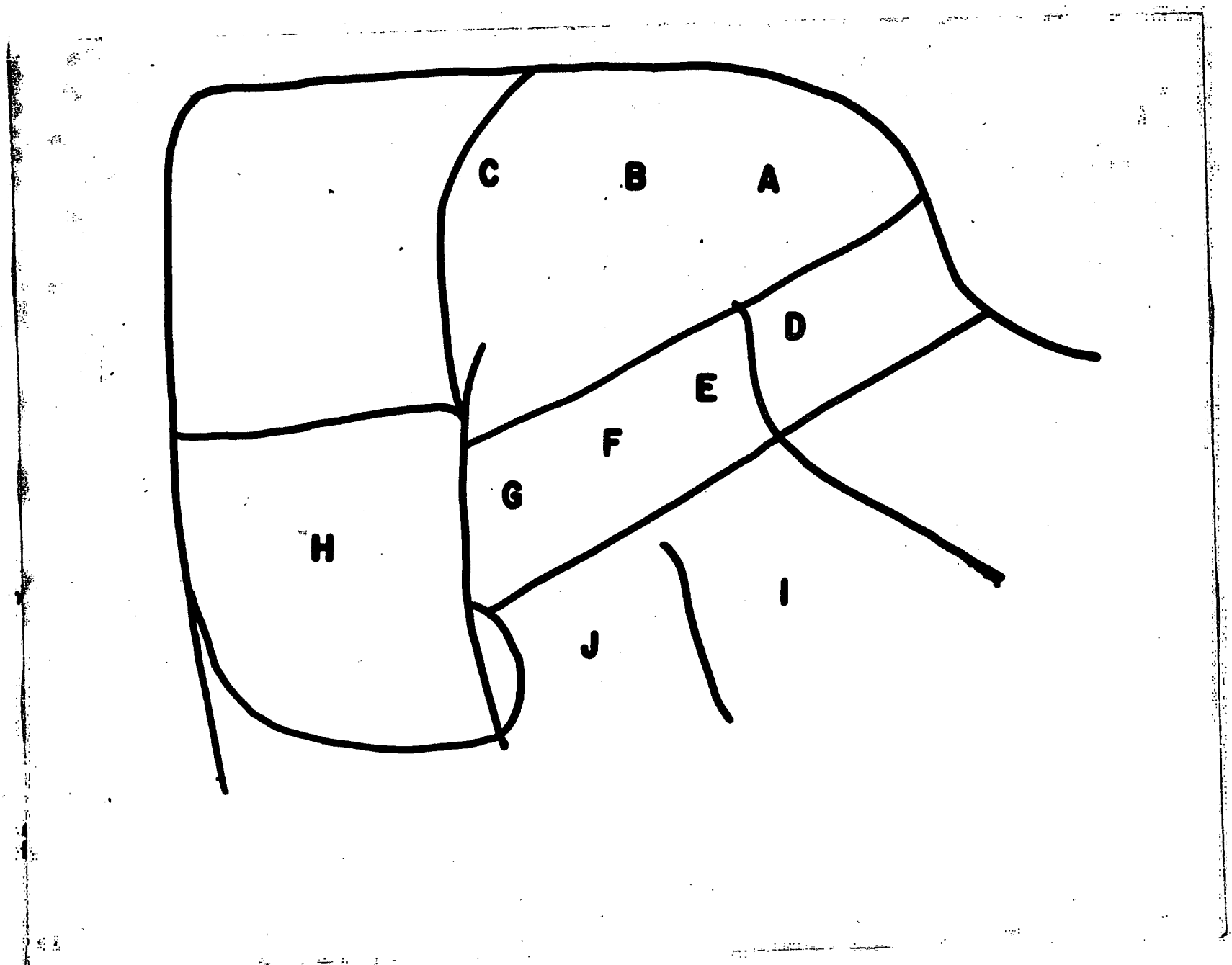

Figure 3. The area bounded by the supra-sylvian sulcus. Areas AI and AII are arbitrarily subdivided into 6 sub-areas.

a consistent deflection of the base line of the oscilloscope. The intensity was reduced in 3 db steps around threshold. A descending series alone was used in determining the threshold. A deflection of the base line 2 out of 5 times at a given intensity level was used as the criterion of response. 2) Response amplitude. The peak to peak response at 15 db above threshold was measured from the film records. Each frame was enlarged approximately 12x for this purpose. 3) Response latency. Both initial and peak latencies were measured from the film records at 15 db above threshold. Appropriate calibration signals were always recorded during the experiment so that the response amplitude and latencies could be expressed in absolute units.

During the experiment the ear to be stimulated and cortical point to be sampled were randomized. In all cases the unstimulated ear was plugged with a piece of oil soaked cotton.

RESULTS

Introduction

Data were obtained from 8 animals; in 4 animals 500 cps was used as the stimulus and in 4 animals 10,000 cps was used as the stimulus. The

results obtained from 6 of the animals will be discussed. Figure 4 contains the outlines of the "auditory areas" studied and the dotted lines indicate the area explored. All corticies have been oriented in the same direction regardless of whether they were right or left lobes. An attempt has been made to follow the lettering of points as indicated in Figure 3.

The data obtained from all animals are presented in Table 1. The points studied are listed in the first column. The same points are not represented in each experiment since it was not always possible to find stable responses in all subdivisions. Median response amplitudes are presented in the first and second columns for both contra-lateral and ipsi-lateral stimulation. The measurements are median peak to peak amplitudes in microvolts. The threshold data are presented in the third and fourth columns. The values presented are in decibels below the 0.5 volt output of the oscillator. Thus the larger the number the lower the threshold. The fifth and sixth columns contain the median initial latencies in milliseconds and were measured from the beginning of the stimulus. The stimulus was displayed on each trace

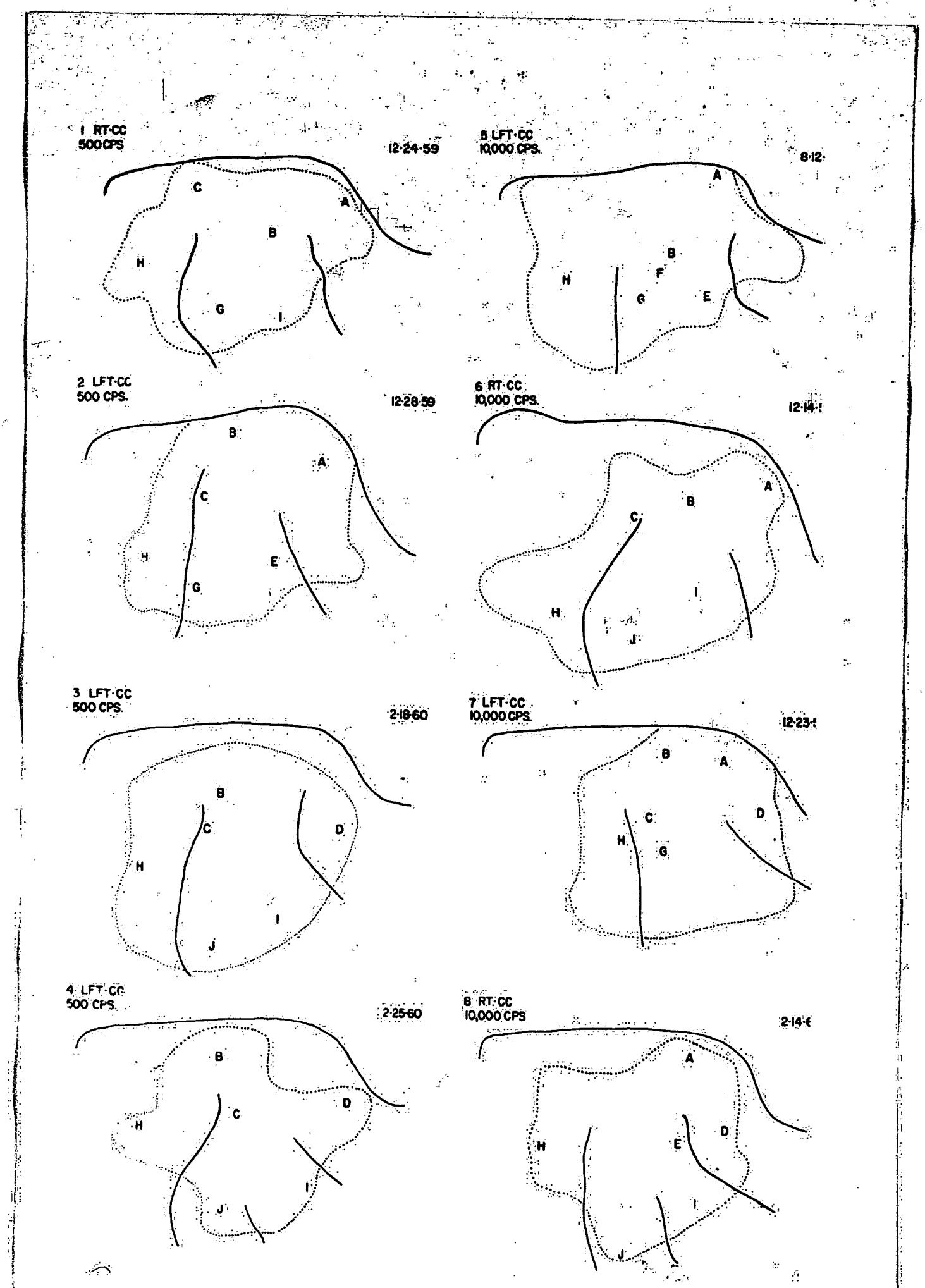

Figure 4. Outlined "auditory areas" studied. The dotted lines indicate the areas explored.

TABLE I

Median amplitudes, thresholds and median latencies for contra-lateral and ipsi-lateral stimulation.

Amplitudes and latencies were measured at 15 db above threshold

Point No.	Ampl. in microvolts C	Ampl. in microvolts I	Thrsld. in decibels C	Thrsld. in decibels I	Init. Lat. in msecs. C	Init. Lat. in msecs. I	Pk. Lat. in msecs. C	Pk. Lat. in msecs. I
			Cat No. 1*					
A	260	254	52	56	14	17	25	25
B	83	112	40	42	14	15	27	30
C	118	106	42	44	15	18	26	31
G	112	71	41	47	21	22	35	35
H	35	41	44	44	17	17	43	22
I	71	59	23	49	14	22	25	30
			Cat No. 2*					
A	41	35	77	49	31	26	44	40
B	94	94	62	34	8	34	38	46
C	94	70	83	52	40	38	67	58
E	148	124	70	47	40	36	60	54
G	94	--	24	--	28	--	58	--
H	59	47	53	34	31	31	48	46
			Cat No. 3*					
B	212	112	80	78	19	19	38	34
C	194	159	76	84	19	19	36	38
D	89	118	76	89	16	16	24	24
H	70	59	34	35	14	14	22	19
I	41	53	71	50	16	16	32	32
J	106	--	32	--	22	--	38	--

(*) indicates 500 cps stimulus source

TABLE I (cont.)

Point No.	Ampl. in microvolts C	Ampl. in microvolts I	Thrsld. in decibels C	Thrsld. in decibels I	Init. Lat. in msecs. C	Init. Lat. in msecs. I	Pk. Lat. in msecs. C	Pk. Lat. in msecs. I
			Cat No. 5*					
A	89	116	58	61	9	8	14	15
B	266	171	49	61	9	17	29	23
E	106	65	47	42	9	16	19	25
F	100	207	46	61	13	10	30	23
G	148	159	42	42	17	8	33	12
H	153	65	47	36	10	12	15	22
			Cat No. 6*					
A	83	130	51	49	9	13	12	22
B	94	59	56	28	10	13	19	20
C	118	207	62	56	14	13	29	32
H	218	--	46	--	10	--	18	--
I	100	136	44	12	14	18	18	29
J	89	--	44	--	20	--	30	--
			Cat No. 7*					
A	83	--	47	--	13	--	21	--
B	159	112	50	52	17	18	23	31
C	313	142	50	51	13	17	30	34
D	159	N-15	44	3	14	N-15	27	N-15
G	100	--	53	--	16	--	28	--
H	106	86	46	37	18	14	29	29

(*) indicates 10,000 cps stimulus source

and was taken from a pair of leads parallel to the input to the transducer. The seventh and eighth columns contain the median peak latencies in milliseconds, again measured from the beginning of the stimulus. All amplitude and latency measurements were made at 15 db above threshold. NR indicates that no response could be evoked. N-15 indicates that data were not obtained at 15 db above threshold since these intensities were beyond the limitations of the apparatus as used in the present experiment.

For analysis of the difference in amplitude between points within each animal for contra-lateral stimulation or ipsi-lateral stimulation, Tukey's test for significance of difference has been used (7). This method assumes that the variances are homogeneous between the samples being compared. Since this was not achieved in all cases the analysis had to be used with discretion. Reference will be made to this at a later time in the discussion.

For present purposes a difference greater than 6 db between the thresholds will be used as the criterion of difference. The choice of this criterion rests on the fact that around threshold the intensity was changed in 3 db steps.

A difference of 2 msecs. has been arbitrarily chosen as the criterion of difference for latencies. This is based on the fact that latencies were read to about 0.5 msec. accuracy and the longest synaptic transmission time would be about 1.5 msecs.

For analysis of the difference between contra-lateral stimulation and ipsi-lateral stimulation when all points were combined, a two-way analysis of variance was employed (4).

Comparison between responses to contra-lateral stimulation versus ipsi-lateral stimulation.

Analysis of response amplitude: A two-way analysis of variance with F set at the 0.01 level of significance showed that in 4 animals the amplitudes of response to contra-lateral stimulation were significantly larger than to ipsi-lateral stimulation (Cats 2, 3, 5 and 7). This relationship is shown in Table II. In 1 animal (Cat 1) there was no significant difference in response amplitude to contra-lateral or ipsi-lateral stimulation. Finally in 1 animal (Cat 6) the amplitudes of response were greater to ipsi-lateral stimulation. In this case only the responses to 4 points could be compared.

TABLE II

F values for two-way analyses of variance

for amplitudes and latencies

Cat No.	Response Amplitude*	Initial Latencies*	Peak Latencies*
1	3.09^{n}	14.76^{i}	18.74^{i}
2	16.49^{c}	6.19^{n}	19.73^{c}
3	18.60^{c}	1.23^{n}	4.21^{n}
5	8.30^{c}	7.18^{c}	6.23^{n}
6	14.27^{i}	27.74^{i}	93.84^{i}
7	36.72^{c}	2.95^{n}	53.71^{i}

(*) indicates 0.01 confidence level was used in all analyses
(c) indicates that contralateral value is significantly greater than ipsi-lateral value
(i) indicates that ipsi-lateral value is significantly greater than contra-lateral value
(n) indicates no significant difference in contra-lateral versus ipsi-lateral stimulation

Analysis of threshold of response: It was impossible to do an analysis of variance on these data, in view of the way the data were obtained, so that it will only be possible to compare points. Data on 36 points could be compared. The threshold for 18 points was lower for contra-lateral versus ipsi-lateral stimulation. The threshold for 6 points was higher for contra-lateral stimulation versus ipsi-lateral stimulation. The threshold for 12 points was the same for contra-lateral versus ipsi-lateral stimulation.

Analysis of initial latencies: A two-way analysis of variance showed that the initial latency to contra-lateral stimulation was shorter for 2 animals (Cats 1 and 6). The initial latency was shorter to ipsi-lateral stimulation for 1 animal (Cat 5) and finally there was no difference in initial latency for contra-lateral versus ipsi-lateral stimulation in 3 animals (Cats 2, 3 and 7).

A point to point analysis shows that the initial latencies of 10 points were lower for contra-lateral versus ipsi-lateral stimulation. The initial latencies for 7 points were higher for contra-lateral versus ipsi-lateral stimulation. Finally the initial

latencies were the same for 12 points for contra-lateral versus ipsi-lateral stimulation.

Analysis of peak latencies: A two-way analysis of variance showed that peak latencies were significantly shorter for contra-lateral versus ipsi-lateral stimulation in 3 animals (Cats 1, 6 and 7). The peak latencies were longer for contra-lateral versus ipsi-lateral stimulation in 1 animal (Cat 2). Peak latencies were no different for contra-lateral versus ipsi-lateral stimulation for 2 animals (Cats 3 and 5).

The peak latencies were shorter for contra-lateral versus ipsi-lateral stimulation for 12 points. The peak latencies were longer for contra-lateral versus ipsi-lateral stimulation for 10 points and there was no difference in peak latencies for 7 points for contra-lateral versus ipsi-lateral stimulation. No comparison could be made for 7 points.

Wave Shape: Plates I and II contain the evoked responses, obtained at 15 db above threshold to contra-lateral and ipsi-lateral stimulation for Cats 1 and 5.

The points from which the responses were evoked are listed in the first column. Some of the traces are single sweeps and in other cases they are multiple traces.

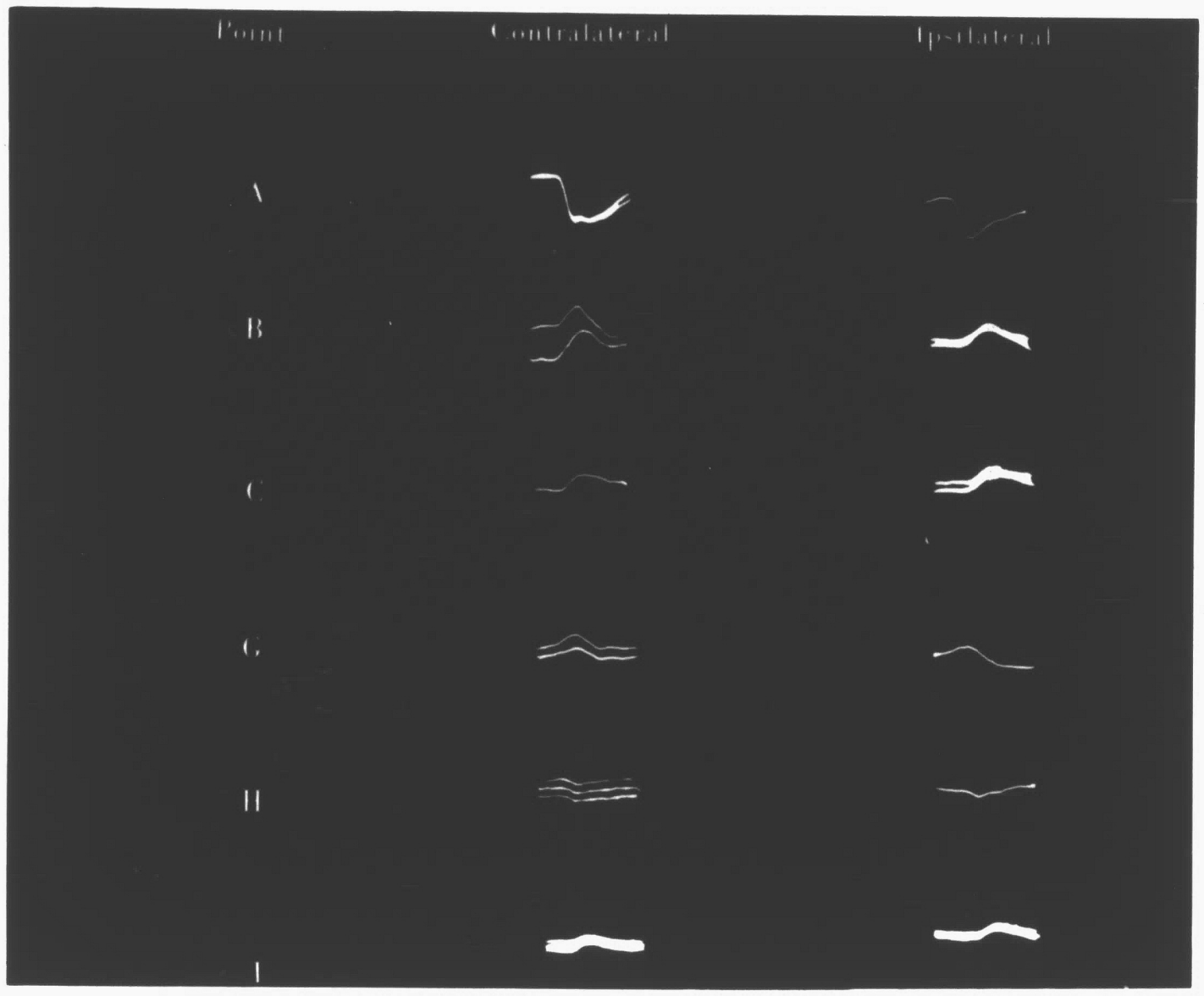

Plate I. Contra-lateral and ipsi-lateral wave shapes. Cat No. 1, 500 cps.

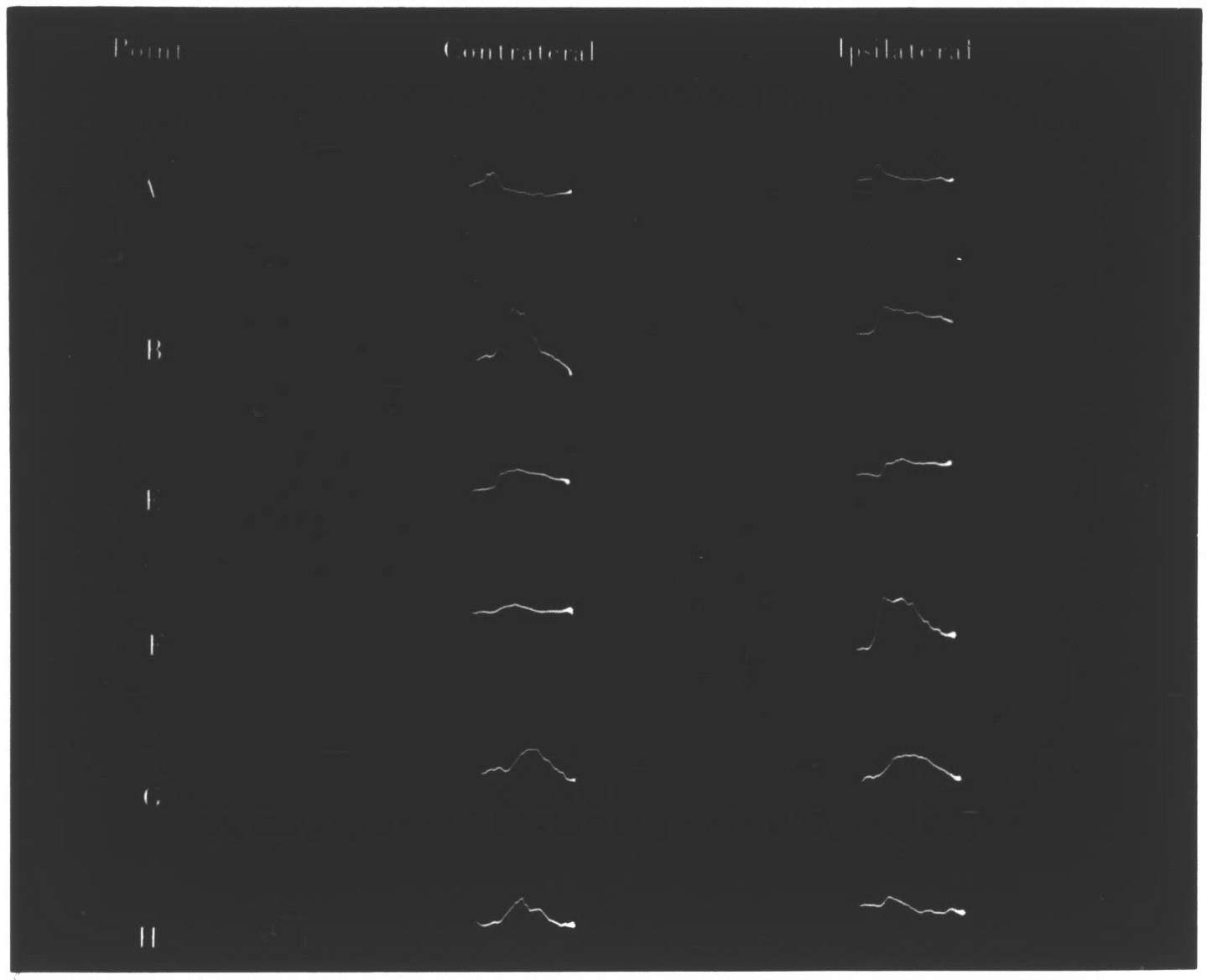

Plate II. Contra-lateral and ipsi-lateral wave shapes. Cat No. 5, 10,000 cps.

In most cases the wave shapes are essentially the same. However, there are cases where the evoked response to contra-lateral stimulation appears to be more complex than to ipsi-lateral stimulation and vice-versa.

Contra-lateral stimulation

Analysis of amplitudes: Table III contains the results of Tukey's multiple comparison test based on the raw data (7). The lines under the numbers indicate that the numbers are not statistically different from each other. The lines above the numbers indicate that the variance is so large as to question the interpretation of two scores as being significantly different from each other even though Tukey's test indicates that they are significantly different. The difficulty, again, arises from the fact that the variances are not always homegeneous as stipulated in the statistical method.

In all animals it was possible to obtain stable evoked responses to contra-lateral stimulation from points in AI, AII and Ep. It was not always possible to obtain stable responses from Tp or In. As a result, comparisons are not always possible within an animal

TABLE III

Results of Tukey's multiple comparison test based on uncorrected amplitudes. See text for explanation

Cat No.	Contra-lateral Points					
1*	A	C	G	B	I	H
	44.7	19.3	17.2	16.7	12.4	6.8
2*	E	C	B	G	H	A
	25.8	16.4	15.3	11.9	10.4	6.7
3*	B	C	D	H	I	
	37.9	32.4	22.5	13.2	7.6	
5**	B	G	H	F	A	E
	46.9	27.0	25.6	18.3	17.2	16.9
6**	H	C	I	A	B	J
	39.4	19.2	18.4	15.0	14.9	13.2
7**	C	D	B	H	G	A
	50.1	32.6	27.6	19.5	16.4	13.4

(*) indicates 500 cps stimulation
(**) indicates 10,000 cps stimulation

TABLE III (cont.)

Cat No.	Ipsi-lateral Points					
1*	A	C	B	G	I	H
	44.7	17.8	14.5	14.4	8.8	7.2
2*	E	B	C	H	A	
	19.9	16.4	13.6	7.9	6.1	
3*	C	D	B	I	H	
	28.3	21.3	16.9	12.4	9.2	
5**	F	B	G	A	E	H
	34.5	28.8	24.7	17.6	10.7	8.8
6**	C	A	I	B		
	32.6	27.0	23.4	16.8		
7**	C	B	H			
	23.4	17.7	13.3			

(*) indicates 500 cps stimulation
(**) indicates 10,000 cps stimulation

for points within all 5 subdivisions of the auditory system chosen for study.

Analysis of Tables I and III indicates that the point from which the largest response was evoked was in AI or AII in 5 out of the 6 animals (Cats 1, 2, 3, 5 and 7). In the case of Cat 6 the largest response occurred in Ep, but, because of the large variance at all points, it may be that the amplitude of the evoked response was the same at all points.

In the 3 animals for which 500 cps was used as the stimulus the points of largest response were not always found in the region of the posterior ecto-sylvian sulcus. Likewise, for the 3 animals for which 10,000 cps was used as the stimulus the points of largest response were not always found in the region of the anterior ecto-sylvian sulcus.

Points in Ep, Tp and In show no consistent trend in relation to AI and AII. In several cases the amplitudes in these subdivisions were larger than <u>some</u> points found in AI or AII or were not different from the amplitudes found in AI and AII when the variances are taken into consideration.

<u>Analysis of thresholds:</u> The lowest threshold was always associated with points in AI. However, the

threshold for points in the posterior region of AI were not the lowest when a 500 cps stimulus was used nor were the thresholds always the lowest in the anterior region when a 10,000 cps stimulus was used.

In all of the 6 animals (Cats 1, 2, 3, 5, 6 and 7) the threshold in Ep was at least 6 db higher than the lowest threshold found in AI or AII. In 3 cases the thresholds in Ep were not different from <u>some</u> points in AI and AII.

Stable evoked responses could be obtained in In in only 3 of the 6 animals (Cats 1, 3 and 6). The thresholds for 2 of these points (Cats 1 and 6) were higher than the thresholds for all points in AI. Unfortunately, because of the small sample, comparison of Tp with points in AI, AII, Ep and In is not warranted.

<u>Analysis of initial latencies:</u> If one employs the criterion that a difference in latency has to be 2 msecs. or greater, then there appears to be no actual trend in the data. Responses in any of the subdivisions studied may be as short as those found in AI. Responses in AII may be longer than those found in AI, Ep, Tp or In. Initial latencies of responses in Ep, Tp or In may be as short or shorter than those found in AI or AII.

Analysis of peak latencies: The analysis of peak latencies results in the same type of conclusions as stated above for initial latencies.

Ipsi-lateral stimulation

Introduction: As indicated in the procedure section the points chosen for study within the various subdivisions were based on contra-lateral stimulation. Fifteen points were studied in AI and only in one case (Cat 7) was it not possible to evoke responses from the same point when ipsi-lateral stimulation was used. The limitation again was the intensity range of the sound system. In the 7 points studied in AII, no responses were evoked when ipsi-lateral stimulation was used (Cats 2 and 7). A response to ipsi-lateral stimulation could not be evoked in one of the 6 points studied in the Ep area (Cat 6). Points in In were studied in 3 animals and responses to both contra-lateral and ipsi-lateral stimulation were obtained (Cats 1, 3 and 6). Points in Tp were studied in 2 animals and in neither case could ipsi-lateral stimulation evoke a response from these points (Cats 3 and 6).

Analysis of amplitude of response: Analysis of the data in Tables I and III shows that the points

from which the largest evoked responses recorded were found in AI or AII in 5 of the 6 animals (Cats 1, 2, 3, 5 and 7). Evoked responses from some points within Ep, Tp or In were equal to or larger than evoked responses recorded from some points within AI or AII. There is, therefore, no consistant relationship between the magnitude of the evoked response and the subdivision from which recordings were made.

When a stimulus of 500 cps was used the largest responses were not consistently found in the region of the posterior ecto-sylvian sulcus. Also, the largest response amplitudes to 10,000 cps stimulation were not consistently found in the region of the anterior ecto-sylvian sulcus.

Analysis of thresholds: In 3 of the 6 animals studied (Cats 1, 6 and 7) the lowest thresholds were obtained from points in AI. In 2 animals (Cats 2 and 3) the equally low thresholds were obtained from points in AI and AII and in the remaining 1 animal (Cat 5) the equally low thresholds were obtained from points in AII and Ep. Thresholds for points within Areas Ep, Tp and In were in some cases not different from the thresholds at some points in AI and AII.

Analysis of initial latencies: In 4 animals (Cats 1, 2, 5 and 6) the lowest initial latencies were recorded from points in AI. In 1 animal (Cat 3) the initial latencies were equal for points in AII, Ep and In. Finally, in 1 animal (Cat 7) the lowest latency was recorded from Ep.

Analysis of peak latencies: In 2 animals (Cats 2 and 6) the lowest peak latencies were found in AI. In 1 animal (Cat 5) the lowest peak latency was recorded from AII. Finally, in 3 animals (Cats 1, 3 and 7) the lowest peak latencies were recorded from Ep.

DISCUSSION

If it is assumed that there are more contra-lateral fibers in the auditory system than ipsi-lateral fibers, this advantage can be expressed in the following ways: 1) Responses to contra-lateral stimulation can be recorded over a larger area than responses to ipsi-lateral stimulation. 2) Responses to contra-lateral stimulation can be larger than to ipsi-lateral stimulation. 3) Thresholds to contra-lateral stimulation might be lower than to ipsi-lateral stimulation since there is a greater possibility of summation. 4) If contra-lateral connections are more direct than ipsi-lateral

connections, then the initial latencies to contra-lateral stimulation should be shorter than to ipsi-lateral stimulation. Finally, 5) If contra-lateral connections are more direct than the responses to ipsi-lateral stimulation, responses to contra-lateral stimulation should peak before the responses to ipsi-lateral stimulation.

The data of the experiments reported here bear on all points but the first. The analysis of variance of the data showed that responses in terms of amplitude to contra-lateral stimulation were larger than to ipsi-lateral stimulation in 4 of the 6 animals. The comparison of thresholds between contra-lateral and ipsi-lateral stimulation fails to show that thresholds are consistantly lower to contra-lateral stimulation. Neither the analysis of variance of initial latencies or peak latencies, nor a consideration of a point by point analysis of latencies showed a significant difference in favor of contra-lateral stimulation. It would appear then that the data show a significant difference in favor of contra-lateral stimulation for amplitude of response alone. The consistent picture that would be expected in favor of contra-lateral stimulation for thresholds and latencies then does not

emerge. The reasons for this discrepancy are not apparent from the data at hand. It is suggested that a combination of an anatomical study of the brains, which have been used in evoked potential studies, is needed. By this means, a correlation between anatomical data concerning contra-lateral versus ipsi-lateral stimulation and evoked potentials could be obtained from the same animals.

Studies of evoked potentials to auditory stimulation have shown that responses to tones can be recorded from areas not previously known to respond to auditory stimulation. Data from 5 subdivisions of the auditory system have been recorded in the present study. The question of interest is whether these subdivisions can be differentiated in terms of contra-lateral versus ipsi-lateral stimulation. Again, data concerning amplitude of response, threshold and latencies are available to relate to the question.

In several instances where stable responses could be obtained to contra-lateral stimulation, no evoked responses could be obtained from these points for ipsi-lateral stimulation. This was particularly true for areas Tp and In. However, it is also true that occasionally <u>some</u> points within AI, AII and Ep were

not responsive to ipsi-lateral stimulation. A generalization, therefore, cannot be drawn.

In general, the largest responses were recorded from AI or AII. However, responses in Ep, Tp and In were equal in amplitude to some points in AI and AII. In the procedures it will be recalled that these areas were explored in order to pick the largest and most stable responses in each of the subdivisions. These data indicate that one is most likely to record the largest responses from Area AI and AII but that the responses from the other subdivisions may be as large as responses surrounding the area of focal response. The anatomical basis for this is not known at the present time.

The lowest thresholds were always associated with points in AI. Some thresholds in AII, Ep, Tp and In, however, were as low as some thresholds in AI. There seems to be no trend in either the initial latencies or peak latencies between the points studied in the various subdivisions.

The analysis of the data obtained to contralateral stimulation is essentially the same as the data obtained to ipsi-lateral stimulation.

To summarize then, the only criterion of response to yield a difference between subdivisions is amplitude of the evoked response. The largest evoked response is most likely to be found in Areas AI or AII. Thresholds and latencies do not seem to be adequate criteria to differentiate the subdivisions. Frequency does not appear to be an important variable. There is no adequate basis to explain this difference at the present time.

The data obtained in the present study can be compared to two other studies. Brodgen and others (3), using the conditioned response technique with cats as subjects, investigated the effects on hearing of destroying certain portions of the auditory system. Their results show that the ipsi-lateral fibers in the cat prove to be as significant in terms of hearing as do the anatomically more abundant crossed fibers. Rosenweig (6) recorded contra-lateral and ipsi-lateral responses from auditory Areas AI and AII. The stimulus source was a click. His results show that at each hemisphere of the cortex the response to stimulation of the contra-lateral ear is significantly larger in amplitude than the ipsi-lateral response at 28 locations,

but no difference in 20 locations while in only one case was the ipsi-lateral response larger.

The pure tone data obtained in the present study appears to parallel the results of Rosenweig.

SUMMARY

Evoked potentials were recorded from the 5 subdivisions of the auditory area of the cat. The responses were to a stimulus source of 500 cps for 3 animals and 10,000 cps for 3 animals. Uni-lateral stimulation of first one ear and then the other followed a random sequence. Measurements of response amplitudes, thresholds and latencies were taken.

A comparison of the evoked responses to contra-lateral versus ipsi-lateral stimulation reveals that the only criterion which yields a difference is response amplitude. In 4 of the 6 animals studied the evoked responses were larger to contra-lateral stimulation than to ipsi-lateral stimulation. It appears that responses to contra-lateral stimulation are more likely to be evoked than responses to ipsi-lateral stimulation.

Comparison of evoked responses from 5 auditory subdivisions was made. Response amplitude was the only

measure that showed any differences. Generally, points of largest response occurred in Areas AI and AII. No further differentiation can be made.

In all comparisons, of the measures taken, frequency did not appear to be an important variable.

BIBLIOGRAPHY

1. Ades, H. W. and J. M. Brookhart, The Central Auditory Pathway. J. Neurophysiol., 13, 189-205, 1950.

2. Barnes, W. L., H. W. Magoun and S. W. Ranson, The Ascending Auditory Pathway in the Stem of the Monkey. J. Comp. Neurol., 79, 129-152, 1943.

3. Brogden, W. L., E. Girden, F. A. Mettler and E. A. Culler, Acoustic Value of the Several Components of the Auditory System in Cats. Amer. J. Physiol., 116, 252-261, 1936.

4. Edwards, Allen L., Experimental Design in Psychological Research, Rinehart, New York, 1956.

5. Kemp, E. H., G. E. Coppie and E. H. Robinson, Electric Responses of the Brain Stem to Uni-lateral Auditory Stimulation. Amer. J. Physiol., 120, 304-315, 1937.

6. Rosenweig, M. R., Representations of the Two Ears at the Auditory Cortex. Amer. J. Physiol., 167, 147-158, 1951.

7. Ryan, Thomas A., Multiple Comparisons in Psychological Research. Psychological Bulletin, 56, 26-47, 1959.

8. Woolsey, C. N. and E. M. Walzl, Topical Projection of Nerve Fibers From Local Regions of the Cochlea to the Cerebral Cortex of the Cat. Johns Hopkins Hosp. Bull., 71, 315-344, 1942.

APPENDIX

LEGEND FOR TABLES

Pt. No. - Point Number

Thrsld. In DB - Threshold In Decibels

Amp. - Amplitude

It - Initial Time

Pk. T. - Peak Time

c - Contra-lateral point; i.e., Cc indicates Point C contra-lateral stimulation.

i - Ipsi-lateral point

December 24, 1959 Cat No. 1
Rt. CC 0.5 Volt
Earphone No. 1
Stimulus 500 cps

Uncorrected values at 15 DB above threshold. Time unit = 0.5 msecs. Amplitude unit = 5.9 microvolts.

Pt. No.	Thrsld. In DB	Amp.	It	Pk.T.
Cc	42.0	23	42	68
		22	42	62
		20	42	62
		20	42	62
		20	30	52
		20	30	52
		19	30	52
		18	28	52
		16	28	50
		15	23	48
Ci	43.5	25	44	66
		20	38	64
		19	36	63
		19	36	63
		19	36	62
		18	36	62
		18	36	56
		18	34	56
		17	34	56
		15	34	54
		15	34	50
		12	30	50
Ac	52.0	55	36	50
		54	36	50
		53	36	50
		52	36	50
		50	34	50
		44	28	50
		42	28	48
		38	28	48
		35	28	48
		30	28	47
		29	28	47
		29	22	46

Cont'd. - Cat No. 1

Pt. No.	Thrsld. In DB	Amp.	It	Pk. T.
Ai	55.5	52	38	56
		51	38	54
		48	38	54
		45	38	53
		45	38	52
		44	38	50
		43	30	50
		43	30	50
		42	30	50
		41	30	50
		38	28	50
		38	26	48
Bc	40.0	34	56	60
		24	34	58
		22	30	57
		21	30	54
		18	28	54
		15	28	54
		14	28	52
		14	28	42
		12	28	42
		12	28	42
		10	26	40
		7	26	40
		8	24	38
Bi	42.0	23	32	70
		23	32	62
		22	32	62
		21	32	60
		20	30	60
		19	30	60
		12	30	60
		10	30	59
		10	30	54
		9	30	54
		7	30	52
		7	30	50

Cont'd. - Cat No. 1

Pt. No.	Thrsld. In DB	Amp.	It	Pk. T.
Hc	44.0	10	36	49
		9	36	48
		8	36	46
		8	34	46
		8	34	46
		7	34	46
		6	34	46
		6	34	44
		6	34	44
		6	34	44
		5	34	44
		5	34	44
		4	30	44
Hi	44.0	12	36	50
		9	36	48
		8	36	46
		8	34	46
		8	34	44
		7	34	44
		6	32	44
		6	30	44
		5	30	44
		5	30	44
		5	30	44
Ic	22.5	19	32	52
		18	32	50
		16	32	50
		14	32	50
		13	30	50
		12	28	50
		8	28	48
		8	28	48
		8	28	48
		8	28	48
		8	28	46
		6	28	42

Cont'd. - Cat No. 1

Pt. No.	Thrsld. In DB	Amp.	It	Pk. T.
Ii	49.0	13	50	68
		12	50	68
		11	50	66
		10	48	62
		10	44	62
		10	44	60
		10	44	60
		10	42	59
		7	42	50
		7	42	50
		6	42	50
		4	42	50.
Gc	41.0	24	44	76
		24	44	74
		20	44	72
		20	44	72
		20	42	70
		19	42	70
		19	40	68
		18	40	68
		16	40	68
		15	38	66
		13	38	64
		12	36	64
Gi	47.0	23	50	72
		21	48	72
		19	48	72
		15	46	70
		12	46	70
		12	44	70
		12	44	70
		12	42	68
		12	40	66
		11	38	64
		11	36	64
		10	34	60

December 28, 1959 Cat No. 2
Lft. CC 0.5 Volt
Earphone No. 1
Stimulus 500 cps

Uncorrected values at 15 DB above threshold. Time unit = 1.2 msecs. Amplitude unit = 5.9 microvolts.

Pt. No.	Thrsld. In DB	Amp.	It	Pk. T.
Ac	77.0	9	28	38
		9	28	38
		8	28	38
		7	26	38
		7	26	38
		7	26	37
		7	26	36
		6	26	36
		6	24	36
		6	24	36
		5	24	34
		4	24	34
Ai	49.0	8	24	34
		8	24	34
		8	24	34
		8	24	34
		7	24	34
		7	22	34
		5	22	32
		5	20	30
		5	20	30
		5	20	30
		4	20	30
		4	20	30
Bc	62.0	21	30	38
		19	26	36
		19	24	35
		18	24	35
		17	24	34
		16	24	32
		13	24	32
		12	23	31
		12	22	30
		11	22	30
		10	22	30

Cont'd. - Cat No. 2

Pt. No.	Thrsld.	Amp.	It	Pk. T.
Bi	34.0	20	38	50
		20	36	46
		20	36	46
		18	35	46
		16	34	44
		16	34	42
		16	24	40
		15	22	30
		15	22	30
		14	22	30
		13	22	30
		12	20	30
Cc	83.0	19	38	60
		19	38	58
		18	38	58
		18	34	58
		18	34	58
		17	34	57
		16	34	56
		16	34	54
		16	34	54
		16	34	54
		15	34	54
		14	32	50
		13	32	44
Ci	52.0	19	36	50
		19	36	50
		18	36	50
		17	36	48
		12	34	48
		12	32	48
		11	26	46
		11	26	44
		11	26	44
		10	24	42
		10	24	40

Cont'd. - Cat No. 2

Pt. No.	Thrsld. In DB	Amp.	It	Pk. T.
Hc	53.0	16	28	42
		11	28	40
		11	28	40
		11	28	40
		10	26	40
		10	26	40
		10	26	40
		10	24	40
		9	24	40
		9	24	40
		9	24	39
		9	24	38
Hi	34.0	11	27	40
		10	26	39
		10	26	38
		9	26	38
		8	26	38
		8	26	38
		7	24	37
		7	24	37
		7	24	37
		7	24	36
		6	24	36
		6	24	36
Gc	24.0	20	50	64
		21	44	62
		19	44	60
		17	44	56
		17	42	54
		16	24	48
		5	24	48
		5	24	48
		4	24	48
		4	24	48
		3	24	48

Cont'd. - Cat No. 2

Pt. No.	Thrsld. In DB	Amp.	It	Pk. T.
Gi	NR	NR	NR	NR
Ec	70	35	36	60
		34	36	54
		31	36	54
		28	36	53
		26	36	52
		25	34	52
		25	34	50
		25	34	48
		24	34	48
		24	30	48
		24	30	48
		22	30	46
		20	30	46
Ei	47	24	30	48
		23	30	48
		22	30	46
		21	30	46
		21	30	46
		21	30	45
		20	30	45
		20	30	44
		19	30	44
		18	30	44
		17	30	44
		16	28	40

Cat No. 3

February 18, 1960
Lft. CC 0.5 Volt
Earphone No. 1
Stimulus 500 cps

Uncorrected values at 15 DB above threshold. Time Unit = 1.2 msecs. Amplitude unit = 5.9 microvolts.

Pt. No.	Thrsld. In DB	Amp.	It	Pk. T.
Dc	76.0	33	14	23
		31	14	22
		27	14	22
		27	14	21
		20	14	21
		20	14	20
		18	14	20
		18	14	20
		18	14	20
		18	10	19
		18	10	18
Di	89.0	38	14	22
		36	14	20
		26	14	20
		26	14	20
		24	14	20
		23	14	20
		20	14	20
		17	12	19
		17	12	19
		17	12	19
		15	12	19
		15	12	19
		13	12	18
Bc	80.0	60	20	43
		49	20	36
		42	18	33
		40	18	33
		38	18	33
		37	16	32
		35	16	32
		34	14	30
		32	14	29
		27	14	29
		26	14	29
		23	12	28

Cont'd. - Cat No. 3

Pt. No.	Thrsld. In DB	Amp.	It	Pk. T.
Bi	78.0	26	16	29
		24	16	29
		24	16	28
		20	16	28
		19	16	28
		19	16	28
		19	16	28
		18	15	28
		14	14	27
		13	14	27
		12	14	26
		12	14	24
		9	12	24
Cc	76.0	44	26	34
		42	24	33
		40	18	32
		39	18	32
		36	16	32
		35	16	30
		31	16	30
		30	16	30
		28	16	30
		28	16	30
		26	16	30
		19	14	28
Ci	84.0	38	18	38
		35	18	36
		32	18	36
		30	18	32
		29	18	32
		28	16	32
		26	16	32
		26	16	31
		26	16	30
		26	16	28
		23	14	28
		18	14	28

Cont'd. - Cat No. 3

Pt. No.	Thrsld. In DB	Amp.	It	Pk. T.
Ic	71.0	10	24	30
		10	18	28
		10	18	28
		10	14	27
		10	14	27
		7	14	27
		7	14	26
		7	14	26
		5	14	26
		5	10	20
		3	8	13
Ii	50.0	24	26	34
		22	16	28
		18	15	28
		16	14	28
		12	14	27
		9	14	27
		8	14	26
		8	14	26
		7	14	24
		6	12	24
		6	12	24
Jc	32.0	23	36	52
		22	24	42
		21	22	42
		20	20	40
		19	20	34
		18	20	32
		18	16	32
		17	14	30
		12	14	30
		10	12	30
		7	12	29
		7	10	28

Cont'd. - Cat No. 3

Pt. No.	Thrsld. In DB	Amp.	It	Pk. T.
Ji	NR	NR	NR	NR
Hc	34.0	18	13	20
		17	13	20
		16	12	18
		15	12	18
		14	12	18
		12	12	18
		12	12	18
		11	12	17
		11	10	17
		10	10	16
		9	10	15
Hi	35.0	17	13	18
		16	12	17
		14	12	17
		13	12	17
		13	12	16
		12	12	16
		7	12	16
		5	10	15
		5	10	15
		5	10	15
		3	10	15
		3	4	10

August 12, 1959 Cat No. 5
Lft. CC 0.5 Volt
Earphone No. 1
Stimulus 10,000 cps

Uncorrected values at 15 DB above threshold.
Time unit = 0.65 msecs. Amplitude unit = 5.9 microvolts.

Pt. No.	Thrsld. In DB	Amp.	It	Pk. T.
Ec	47.0	31	29	48
		22	29	42
		22	22	42
		21	18	42
		19	18	38
		18	16	30
		18	15	29
		15	14	19
		14	12	18
		14	12	18
		12	10	17
		7	6	16
		7	6	14
Ei	42.0	13	28	42
		13	26	41
		13	26	40
		13	26	38
		12	26	38
		11	24	38
		11	24	37
		10	24	36
		9	24	36
		8	24	36
		7	15	26
		6	11	23
Bi	61.0	48	19	50
		46	14	48
		34	14	44
		33	13	40
		31	12	38
		30	12	37
		29	11	36

Cont'd. - Cat No. 5

Pt. No.	Thrsld. In DB	Amp.	It	Pk. T.
Bi	61.0	27	11	35
		22	10	34
		22	10	34
		21	8	34
		20	6	32
		20	2	30
Bc	48.5	70	18	46
		61	18	46
		59	16	45
		59	16	45
		58	14	44
		50	14	44
		45	14	44
		42	12	40
		39	10	18
		38	10	18
		37	8	17
		32	6	12
		29	3	11
Gc	42.0	34	33	54
		32	28	54
		29	28	54
		27	26	54
		26	26	52
		26	26	52
		25	26	51
		24	25	48
		24	24	48
		23	24	47
		23	24	46
		23	22	46
		21	22	44
		15	22	44
Gi	42.0	30	16	28
		29	16	24
		28	13	21
		28	13	18
		28	13	18

Cont'd. - Cat No. 5

Pt. No.	Thrsld. In DB	Amp.	It	Pk. T.
Gi	42.0	27	13	18
		25	13	17
		24	10	17
		23	9	16
		22	6	16
		20	4	16
		18	3	8
Hc	47.0	30	18	26
		30	18	26
		29	16	26
		26	16	24
		26	16	24
		26	16	23
		26	14	23
		25	12	23
		24	10	22
		22	6	22
		22	6	22
		21	1	21
Hi	35.5	14	25	41
		14	24	38
		14	24	36
		13	18	36
		11	18	34
		10	18	34
		4	8	7
		3	6	5
		3	5	4
		2	3	3
Ac	57.5	33	15	23
		24	14	22
		22	14	21
		22	14	21
		15	13	21
		14	12	20
		12	12	20
		12	12	17
		10	10	17
		8	9	14

Cont'd. - Cat No. 5

Pt. No.	Thrsld. In DB	Amp.	It	Pk. T.
Ai	60.5	24	15	25
		23	15	24
		22	14	24
		22	13	24
		19	13	23
		18	13	23
		18	12	23
		17	12	23
		16	12	22
		16	12	22
		15	12	22
		15	8	20
		14	8	17
Fc	45.5	25	24	50
		25	24	50
		25	23	50
		23	22	49
		20	21	47
		18	20	46
		16	20	45
		11	20	45
		11	20	45
		10	20	44
		10	18	42
		10	14	41
Fi	61.0	61	20	43
		50	19	41
		44	19	40
		40	18	39
		39	17	37
		36	15	36
		35	15	35
		18	14	34
		13	13	32
		10	12	30
		9	10	30
		9	4	28
		9	4	27

December 14, 1959 Cat No. 6
Rt. CC 0.5 Volt
Earphone No. 1
Stimulus 10,000 cps

Uncorrected values at 15 DB above threshold. Time unit = 0.65 msecs. Amplitude unit = 5.9 microvolts.

Pt. No.	Thrsld. In DB	Amp.	It	Pk. T.
Hc	46.0	70	28	52
		41	26	46
		38	16	31
		36	14	26
		34	10	26
		17	10	21
Hi	NR	NR	NR	NR
Ic	44.0	25	22	32
		19	21	29
		18	21	28
		18	20	26
		17	18	24
		13	18	23
Ii	15.0	36	28	51
		32	28	50
		30	28	48
		24	28	46
		24	28	46
		23	27	44
		19	24	44
		19	24	44
		19	24	43
		19	24	40
		18	24	40
Bc	56.0	18	20	32
		17	18	30
		16	18	30
		16	12	27
		11	8	26
		9	6	26

Cont'd. - Cat No. 6

Pt. No.	Thrsld. In DB	Amp.	It	Pk. T.
Bi	28.0	30	24	54
		18	22	43
		16	22	36
		16	21	36
		15	20	35
		11	20	31
		9	20	28
		7	19	28
		7	18	27
		5	18	26
		5	18	26
		4	17	26
Jc	44.0	19	53	68
		19	40	68
		17	40	66
		16	40	60
		15	40	56
		15	36	52
		14	26	39
		14	24	34
		12	24	34
		11	22	34
		10	22	34
		6	20	32
Ji	NR	NR	NR	NR
Ac	51.0	20	14	19
		19	14	18
		14	14	18
		14	12	18
		12	12	18
		11	12	16
Ai	48.5	38	22	36
		38	22	35
		22	20	34
		20	20	34
		17	20	30

Cont'd. - Cat No. 6

Pt. No.	Thrsld. In DB	Amp.	It	Pk. T.
Cc	62.0	21	24	50
		21	22	50
		20	21	46
		20	20	44
		18	14	44
		15	12	44
Ci	56.0	46	20	52
		44	20	50
		38	20	50
		31	20	48
		27	16	46
		15	10	42

December 23, 1959 Cat No. 7
Lft. CC 0.5 Volt
Earphone No. 1
Stimulus 10,000 cps

Uncorrected values at 15 DB above threshold.
Time unit = 0.65 msecs. Amplitude unit = 5.9 microvolts.

Pt. No.	Thrsld. In DB	Amp.	It	Pk. T.
Ac	47.0	18	18	38
		16	16	34
		16	16	34
		15	16	34
		15	16	34
		15	14	34
		13	14	18
		12	14	18
		11	14	18
		11	12	17
		11	12	17
		10	10	16
Ai	NR	NR	NR	NR
Bc	50.0	38	23	37
		38	23	36
		36	22	36
		34	22	36
		34	22	35
		30	22	34
		25	19	24
		25	19	23
		23	19	21
		23	17	21
		20	17	21
		16	16	21

XX

Cont'd. - Cat No. 7

Pt. No.	Thrsld. In DB	Amp.	It	Pk. T.
Bi	52.0	25	28	48
		23	26	46
		21	24	44
		21	24	43
		20	24	43
		19	22	42
		18	22	42
		17	22	40
		14	22	40
		13	22	38
		11	22	38
		10	21	38
Cc	50.0	78	19	54
		64	17	42
		60	17	42
		59	16	40
		58	14	40
		54	14	40
		52	14	39
		51	14	38
		48	14	36
		46	13	36
		41	12	35
		26	6	35
Ci	51.0	37	24	51
		32	24	50
		26	22	50
		26	20	48
		25	20	47
		24	20	46
		23	18	46
		23	16	45
		21	14	44
		17	14	44
		15	14	44
		12	11	40

Cont'd. - Cat No. 7

Pt. No.	Thrsld. In DB	Amp.	It	Pk. T.
Hc	46.0	32	26	44
		25	24	42
		22	22	39
		22	22	39
		21	22	39
		19	22	39
		18	22	38
		18	20	38
		18	20	38
		16	20	37
		16	20	37
		16	14	37
		13	10	36
Hi	37.0	15	22	42
		15	20	40
		15	18	38
		15	18	38
		15	18	38
		15	16	38
		15	16	38
		13	16	37
		13	16	36
		12	16	36
		10	16	36
		7	14	34
Gc	53.0	20	20	42
		18	20	38
		18	20	38
		18	20	37
		17	18	37
		16	18	37
		16	18	37
		16	18	36
		15	18	36
		13	16	36
		13	14	33

Cont'd. - Cat No. 7

Pt. No.	Thrsld. In DB	Amp.	It	Pk. T.
Gi	NR	NR	NR	NR
Dc	44.0	60	20	41
		58	20	41
		54	18	39
		47	18	39
		44	17	39
		42	16	38
		12	15	30
		12	15	30
		11	14	30
		10	14	30
		10	14	28
		9	14	28
Di	03.0	N-15	N-15	N-15

VITA

Donald David Thompson was born in Christiansburg, Virginia on May 14, 1931, the son of Fannie and Elbert D. Thompson. He graduated from Andrew Lewis High School, Salem, Virginia in June 1951.

On November 10, 1951, he married Virginia L. Smiley. A daughter, Donna Lynn, was born on November 14, 1954. A son, Donald David, Jr., was born on June 7, 1960.

Upon completion of military service with the United States Army, he entered the University of Virginia in September of 1954. In June 1958, he received the degree of Bachelor of Arts in Psychology from the University of Virginia. He entered Lehigh University in September of 1958 where he served as a research and teaching assistant in the Department of Psychology. In October 1960, he received the Master of Science degree in Psychology.